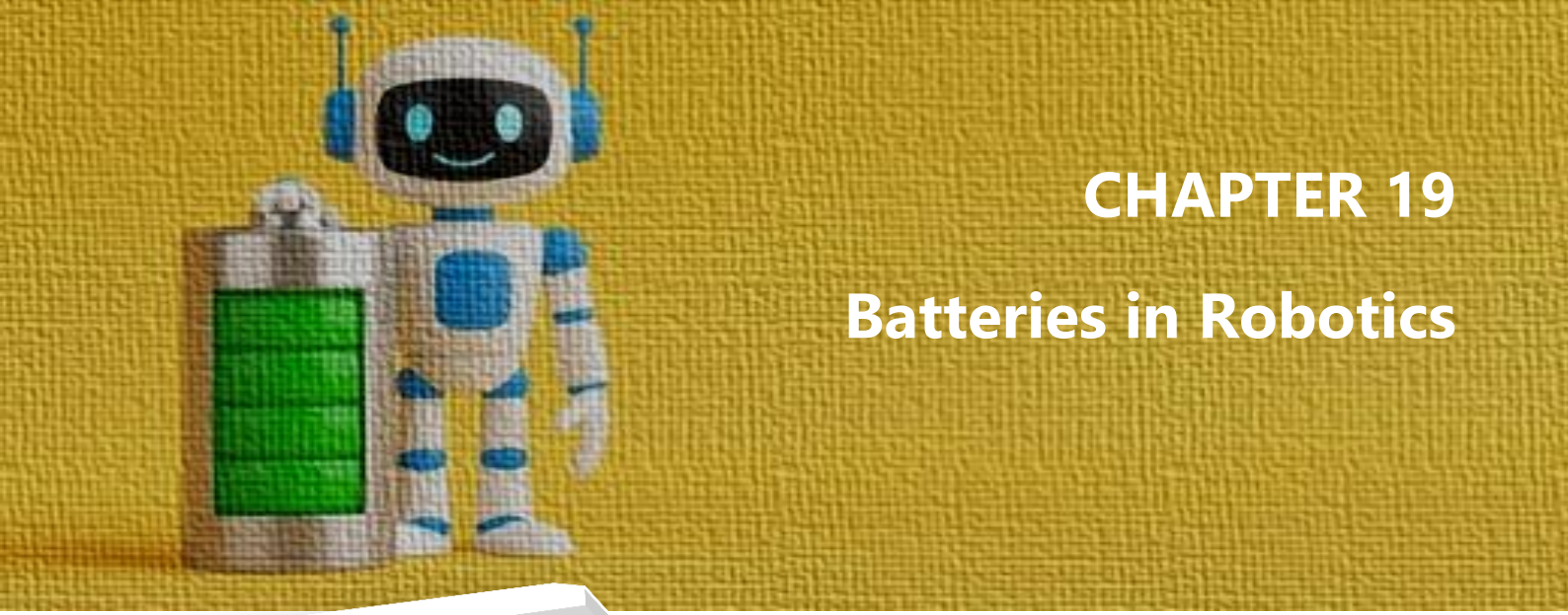


CHAPTER 19

Batteries in Robotics

Learning Outcomes

- Introduction to Frames & Reference Frame
- Applications of Frame
- Comparison

In the world of robotics, one of the most important components is the battery. Just like humans need food to function, robots need electrical energy to perform their tasks. This energy is provided by batteries, which serve as portable power sources. Batteries are essential in robotics because they allow the robot to move, sense, think, and perform actions—without being tied to a power outlet. Whether it's a simple line-following robot or a complex drone, batteries form the backbone of the robot's power system.

A battery stores energy chemically and releases it as electrical power when needed. This electrical energy runs the motors, sensors, controllers, and other electronic components in a robot. In this chapter, you will explore what batteries are, why they are crucial in robotics, the different types used, how they work, where they are applied in real life, and their advantages and disadvantages.

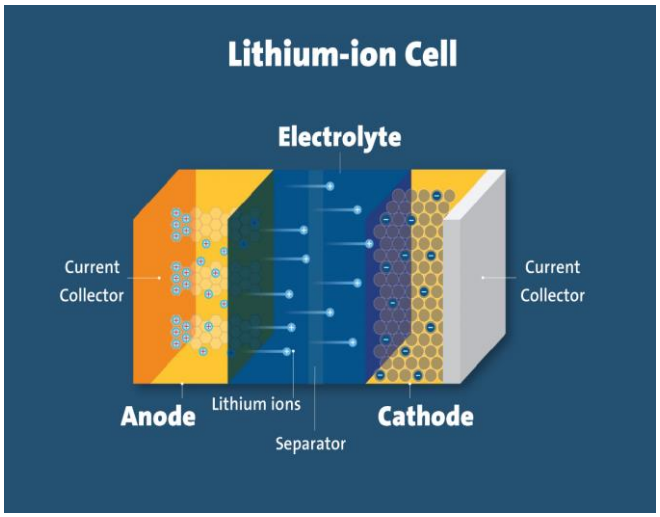
What is a Battery and Why Is It Important in Robotics?

A battery is a device that converts stored chemical energy into electrical energy. In robotics, this electrical energy powers all the major components of the robot, such as the microcontroller (brain), motors (movement), and sensors (perception). One of the main advantages of using batteries is that they provide mobility-robots can move around freely without depending on a direct electric plug. Choosing the right battery is critical because different robots have different power needs. For example, a robotic vacuum cleaner needs long battery life and quick charging, whereas a heavy warehouse robot needs a battery that can deliver a high amount of current even if it is large and heavy.

Types of Batteries Used in Robotics

Although there are many types of batteries in the market, two of the most commonly used in robotics are **Lithium-Ion (Li-ion)** batteries and **Lead-Acid** batteries. Each type has its own characteristics, working principles, applications, benefits, and drawbacks.

1. Lithium-Ion (Li-ion) Batteries

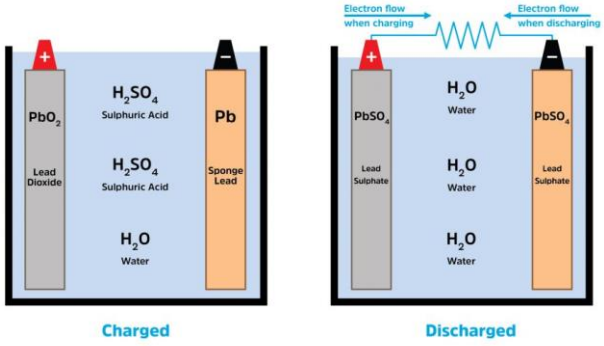


Lithium-ion batteries are widely used in modern robots due to their high energy density, light weight, and ability to recharge many times. These are the same batteries used in smartphones, laptops, drones, and electric vehicles. In robotics, Li-ion batteries are ideal for mobile robots where weight and space are important.

The working principle of a Li-ion battery involves the movement of lithium ions between the anode and cathode through an electrolyte. This movement generates electricity, which is then used by the robot. These batteries charge quickly, last long, and don't lose much charge when not in use. They are especially useful in smart and fast-moving robots like drones, robotic arms, and autonomous delivery robots.

However, Li-ion batteries are more expensive than other types and require protection circuits to prevent overcharging, overheating, or short circuits. If damaged or misused, they can catch fire or explode. That's why careful handling and proper charging systems are essential.

2. Lead-Acid Batteries



Lead-acid batteries are one of the oldest types of rechargeable batteries. They are commonly used in large robots, electric wheelchairs, and automated guided vehicles in factories. These batteries are heavier and bulkier but are reliable and capable of delivering a large amount of current in a short time. Lead-acid batteries operate using lead plates and sulphuric acid. When connected, a chemical reaction between the plates generates electricity. These batteries are robust, cost-effective, and suitable for applications where weight is not a major concern. They are often found in emergency robots, solar-powered systems, and robotics training platforms. On the downside, lead-acid batteries are heavy and take longer to charge. They also have a shorter lifespan and may leak acid if damaged, making them less suitable for portable or delicate robotic systems.

Comparison between Lithium-Ion and Lead-Acid Batteries

Feature	Lithium-Ion Battery	Lead-Acid Battery
Weight	Lightweight	Heavy
Size	Compact and small	Bulky and large
Energy Density	High (stores more energy in less space)	Low
Charging Time	Fast	Slow
Lifespan	Long (more charge cycles)	Shorter lifespan
Cost	Expensive	Cheaper
Maintenance	Low maintenance	Requires regular maintenance (checking water levels)
Safety	Risk of fire or explosion if mishandled	Safer but can leak acid
Applications	Drones, mobile robots, smartphones, laptops	Wheelchairs, factory robots, UPS systems
Suitability	Best for mobile, lightweight, and advanced robots	Best for large, heavy, or stationary robots

Applications in Real-World Robots

Different robotic systems require different power solutions. A small mobile robot for a science fair may use a Li-ion battery due to its lightweight design. A robotic vacuum cleaner uses Li-ion batteries for long run-time and portability. On the other hand, industrial robots or robotic trolleys used in logistics may use lead-acid batteries because they can handle high current loads and are more cost-effective. Here are some examples:

- **Drones** use Li-ion batteries for their lightweight and high power.
- **Robotic vacuum cleaners** need Li-ion for long battery life and portability.
- **Robotic wheelchairs** and **factory AGVs** use lead-acid batteries due to their strength and durability.

Charging, Safety, and Maintenance

Taking care of batteries is very important in robotics. Both Li-ion and lead-acid batteries must be charged using the right charger. Overcharging or using the wrong charger can damage the battery or even cause accidents. Batteries should always be stored in cool, dry places away from sunlight or heat sources. Good battery practices include:

- Avoiding full discharge repeatedly
- Not exposing to extreme temperatures
- Never puncturing, crushing, or throwing batteries into fire
- Using protection circuits to manage charging safely

How to Choose the Right Battery for a Robot

To select the correct battery, students and engineers must understand the power requirement of their robot. If the robot needs to be light and mobile, then a lithium-ion battery is the better

option. If the robot is heavy and used in a fixed place or moves slowly, then a lead-acid battery might be suitable. Here are some key questions to consider:

- **How much current does the robot need?**
- **How long should the robot run before recharging?**
- **What is the weight limit of the robot?**
- **Is quick charging important?**
- **What is the budget for the battery?**

Real-World Applications of Batteries

Batteries are essential for powering devices and machines that cannot be connected to electricity all the time. In robotics, batteries are the main source of power for making the robot move, sense the environment, and perform tasks. Below are some real-world applications of batteries:

1. Mobile Robots

Mobile robots like **line-following robots, obstacle-avoiding robots, or delivery robots** use batteries for movement and control.

- **Battery Type Used:** Mostly **Lithium-ion** or **Lithium Polymer (Li-Po)** batteries are used because they are lightweight and provide high power.
- **Example:** A warehouse robot that picks and delivers items uses a rechargeable lithium-ion battery to run for hours without being plugged in.

2. Drones and UAVs

Drones are robotic flying devices used in photography, military surveillance, delivery, agriculture, and rescue operations.

- **Battery Type Used: Lithium-ion or Li-Po** batteries are preferred because they are light and powerful.
- **Why Important:** Drones need powerful batteries that can provide energy without adding much weight.
- **Example:** Amazon Prime Air uses drones powered by Li-Po batteries to deliver packages.

3. Autonomous Cars and Electric Vehicles (EVs)

Robotic cars and electric vehicles run entirely on battery power.

- **Battery Type Used:** Large **Lithium-ion battery packs** are used for long-lasting performance.
- **Example:** Tesla electric cars use advanced lithium-ion battery systems to travel over 400 km on a single charge.

4. Medical Robots and Equipment

Batteries power life-saving robotic devices like surgical robots, wheelchair robots, or prosthetic limbs.

- **Battery Type Used:** Both **Li-ion** and **Lead-acid** batteries are used, depending on the size and function of the robot.
- **Example:** Battery-powered robotic prosthetic legs can help amputees walk and run.

5. Home Automation and Assistive Robots

Robots used in homes for cleaning, assisting the elderly, or smart surveillance systems rely on batteries.

- **Battery Type Used:** Mostly **Lithium-ion** for rechargeable convenience.
- **Example:** Vacuum cleaning robots like **Roomba** run on lithium-ion batteries and clean floors without human help.

6. Industrial Robots

Some industrial robots that work in locations without stable electricity use large batteries to stay operational.

- **Battery Type Used: Lead-acid** for low-cost and longer duration or **Lithium-ion** for efficiency.
- **Example:** A robotic arm in a solar farm, used for panel cleaning, uses battery power to function in remote areas.

7. Agricultural Robots

Robots used for planting, spraying pesticides, or monitoring crops use batteries for field operations.

- **Battery Type Used: Lithium-ion** batteries, as they need to be efficient and last long in outdoor conditions.
- **Example:** A solar-charged robot that detects weeds and sprays pesticides only when needed.

8. Military and Defence Robots

Robots used by armed forces for bomb disposal, surveillance, or patrolling use rugged batteries.

- **Battery Type Used:** High-performance **Lithium-ion** or **customized military-grade batteries**.
- **Example:** PackBot robots used by the US Army are battery-powered and can work in dangerous areas.

9. Space Robots and Satellites

Batteries are used in space missions where sunlight may not be available all the time.

- **Battery Type Used:** Advanced **Lithium-ion** batteries paired with solar charging systems.
- **Example:** Mars rovers like **Curiosity** and **Perseverance** use battery systems to work during night or dust storms.

10. Educational and DIY Robots

Students and hobbyists use small batteries to build and test robotic projects.

- **Battery Type Used:** Small **Li-ion**, **Li-Po**, or **AA rechargeable batteries**.
- **Example:** A student building a Bluetooth-controlled robot car can use a 7.4V lithium-ion battery pack.

Chapter Highlights

- **Batteries are essential** in robotics as they provide portable power to run motors, sensors, and controllers.
- A **battery converts chemical energy into electrical energy**, allowing the robot to function without being plugged into a power source.
- The **two main types of batteries** used in robotics are:
  - **Lithium-Ion (Li-ion)** – lightweight, rechargeable, high energy density.
  - **Lead-Acid** – heavy, reliable, delivers high current, cost-effective.
- **Lithium-Ion batteries** are suitable for mobile and compact robots like drones, robotic arms, and home assistants.
- **Lead-Acid batteries** are ideal for heavy-duty or industrial robots such as AGVs, robotic wheelchairs, and factory trolleys.
- **Comparison**: Li-ion batteries are lighter and longer-lasting but more expensive; Lead-acid batteries are cheaper but bulkier and slower to charge.
- **Battery safety and maintenance** include using proper chargers, avoiding overheating, and preventing damage to extend battery life.
- **Battery selection depends** on the robot's size, power needs, weight capacity, runtime, and budget.
- **Real-world applications** of batteries include drones, autonomous cars, medical robots, military bots, agricultural robots, and educational robotics kits.

Exercise

Multiple-Choice Questions (MCQs)

1. Which type of battery is most commonly used in modern drones?
   a) Lead-acid
   b) Nickel-cadmium
   c) Lithium-ion
   d) Alkaline
2. Lead-acid batteries are suitable for:
   a) Lightweight robots
   b) Toy cars
   c) Factory robots and AGVs
   d) Smart watches
3. What is the major drawback of lithium-ion batteries?
   a) Slow charging
   b) Heavy weight
   c) Explosive if mishandled
   d) Low energy density
4. A battery converts _____ energy into _____ energy.
   a) Electrical to Mechanical

b) Chemical to Electrical
c) Heat to Light
d) Solar to Thermal

5. Which of the following is NOT a characteristic of Li-ion batteries?
   a) Lightweight
   b) Quick charging
   c) Bulky
   d) High energy density
6. What should be avoided while handling batteries?
   a) Keeping in cool places
   b) Overcharging
   c) Using proper charger
   d) Storing away from sunlight
7. Lead-acid batteries are:
   a) More expensive than Li-ion
   b) Lighter than Li-ion
   c) Cheaper but heavier
   d) Suitable for drones
8. Which of these devices is most likely to use Li-ion batteries?
   a) Solar inverter
   b) Floor cleaning robot
   c) Emergency exit light
   d) Diesel generator
9. What is used to prevent Li-ion battery failure?
   a) Diesel
   b) Overcurrent relay
   c) Protection circuit
   d) Fan
10. What happens if a Li-ion battery is punctured or overheated?
    a) It charges faster
    b) It discharges slowly
    c) It may catch fire or explode
    d) It becomes waterproof

True and False

1. Lithium-ion batteries are heavier than lead-acid batteries.
2. Lead-acid batteries are ideal for mobile drones and robots.
3. Batteries help robots work without being connected to a direct power supply.
4. Battery safety includes avoiding overcharging and high temperatures.
5. All types of batteries are rechargeable.

Fill in the Blanks

1. _____ batteries are commonly used in drones due to their light weight.
2. Lead-acid batteries use _____ acid and lead plates to produce electricity.
3. A battery converts chemical energy into _____ energy.

4. Using a _____ charger can damage a battery or cause safety issues.
5. Li-ion batteries require _____ circuits to ensure safety.

Assertion and Reason

1. **Assertion (A):** Li-ion batteries are preferred in drones.
   Reason (R): They are light and provide high energy.
   a) Both A and R are true and R is the correct explanation.
   b) Both A and R are true but R is not the correct explanation.
   c) A is true but R is false.
   d) A is false but R is true.
2. **Assertion (A):** Lead-acid batteries are ideal for robotic arms used in warehouses.
   Reason (R): These batteries are heavy and have high current delivery.
   a) Both A and R are true and R is the correct explanation.
   b) Both A and R are true but R is not the correct explanation.
   c) A is true but R is false.
   d) A is false but R is true.
3. **Assertion (A):** Overcharging a battery is safe if it's done slowly.
   Reason (R): Batteries can cool themselves down when full.
   a) Both A and R are true and R is the correct explanation.
   b) Both A and R are true but R is not the correct explanation.
   c) A is true but R is false.
   d) A is false and R is false.
4. **Assertion (A):** Li-ion batteries are not suitable for high-current industrial robots.
   Reason (R): They explode when used continuously.
   a) Both A and R are true and R is the correct explanation.
   b) Both A and R are true but R is not the correct explanation.
   c) A is true but R is false.
   d) A is false and R is false.
5. **Assertion (A):** Lead-acid batteries are cheaper than Li-ion batteries.
   Reason (R): The materials used in lead-acid batteries are more common.
   a) Both A and R are true and R is the correct explanation.
   b) Both A and R are true but R is not the correct explanation.
   c) A is true but R is false.
   d) A is false and R is false.

Short Answer Questions

1. What is the role of a battery in a robot?
2. Mention two advantages of using lithium-ion batteries in robotics.
3. Why are lead-acid batteries still used in heavy robots?
4. List two safety precautions to follow while handling robot batteries.
5. What are the key factors to consider while selecting a battery for a robot?

Long Answer Questions

1. Explain the working, benefits, and drawbacks of lithium-ion batteries in robotics.

2. Compare lithium-ion and lead-acid batteries in terms of weight, cost, lifespan, and usage.
3. Describe with examples how batteries are used in real-world robots like drones, AGVs, or prosthetics.
4. How does battery safety impact robot performance and user protection?
5. Write a detailed note on how to maintain batteries to improve their life and efficiency in robotic systems.